THE GREENHOUSE EFFECT

Stephen E. Schwartz

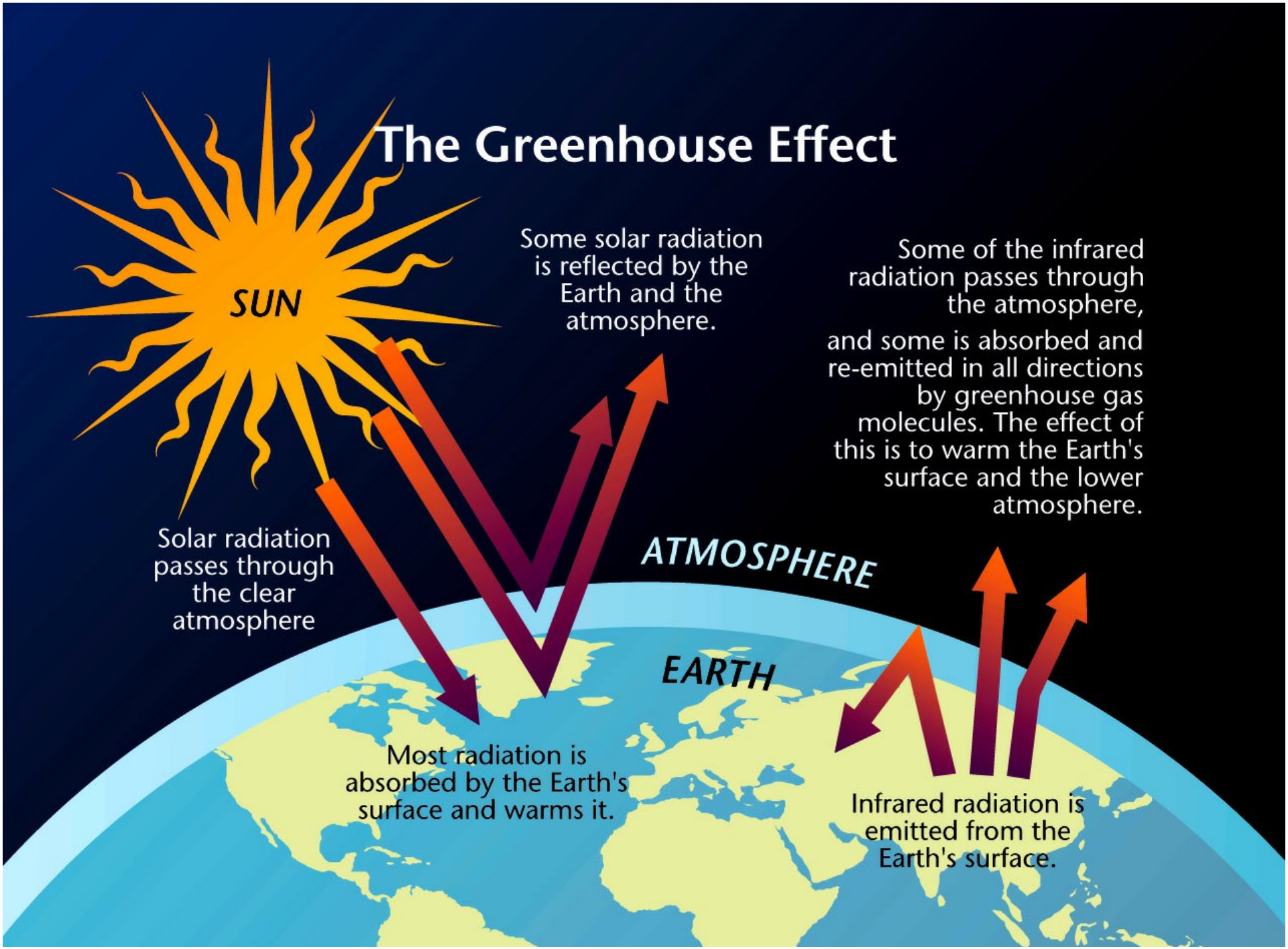
BROOKHAVEN NATIONAL LABORATORY

Atmospheric Sciences Division

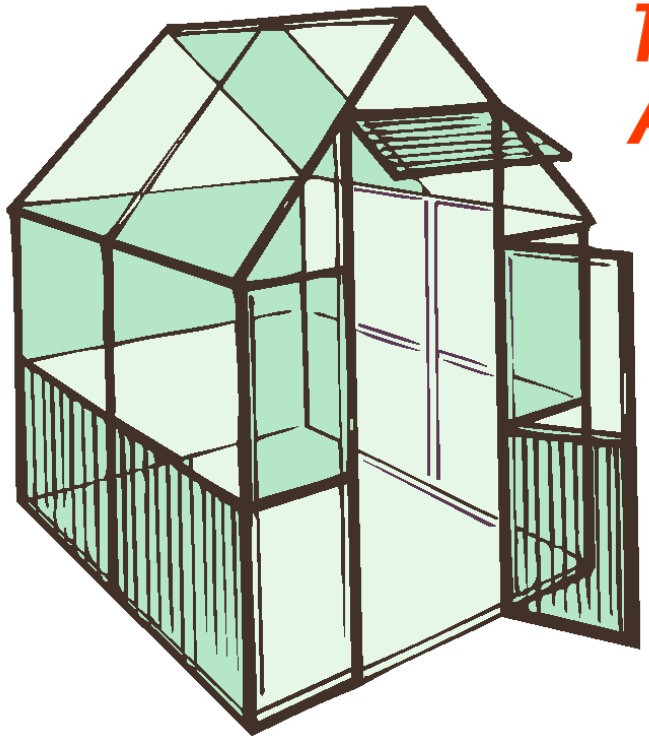
CSSP Lecture

July 27, 2005

http://www.ecd.bnl.gov/steve/schwartz.html


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

THE GREENHOUSE EFFECT



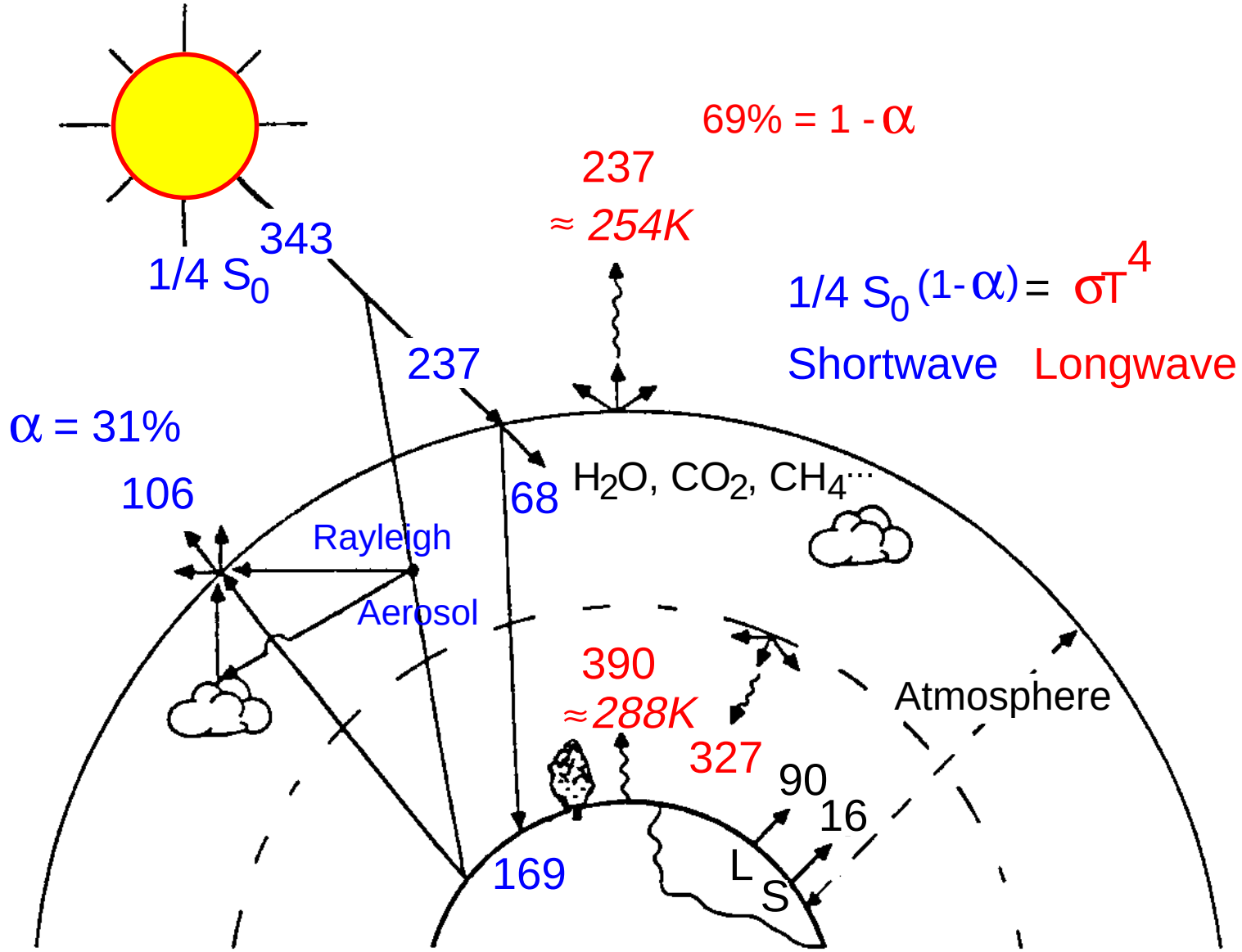
THE EARTH'S ENERGY BUDGET: A DELICATE BALANCE

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

This is the greenhouse effect. Without it, the Earth's climate would be like the moon's, harsh and severe.

GLOBAL ENERGY BALANCE

Global and annual average energy fluxes in watts per square meter



Schwartz, 1996, modified from Ramanathan, 1987

ATMOSPHERIC RADIATION

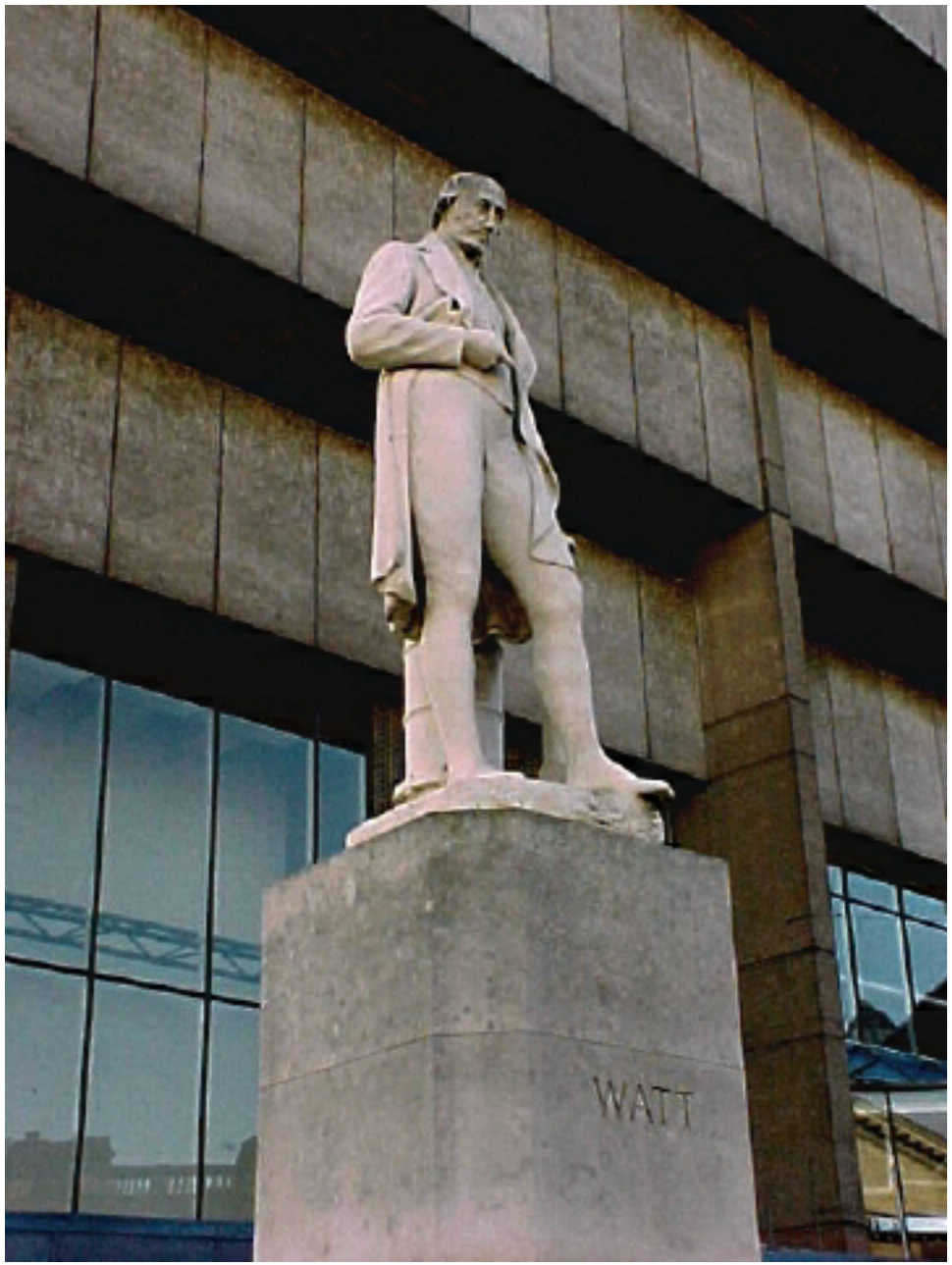
Energy per area per time

Power per area

Unit:

Watt per square meter

$W\ m^{-2}$



Everybody talks about the weather —

But nobody does anything about it.

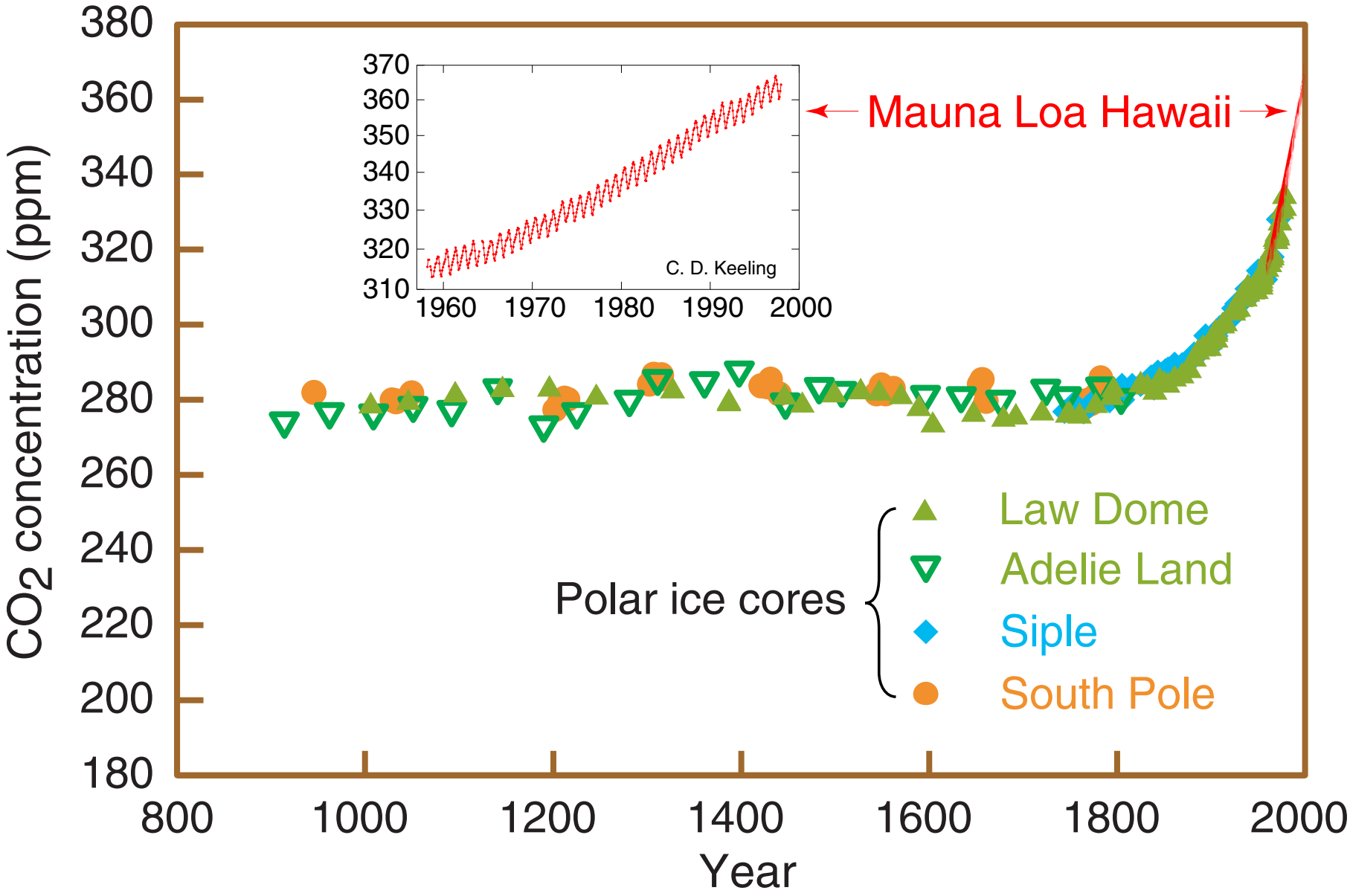
– Mark Twain

Now with the greenhouse effect,
we ARE doing something about it.
What are we doing?

RADIATIVE FORCING

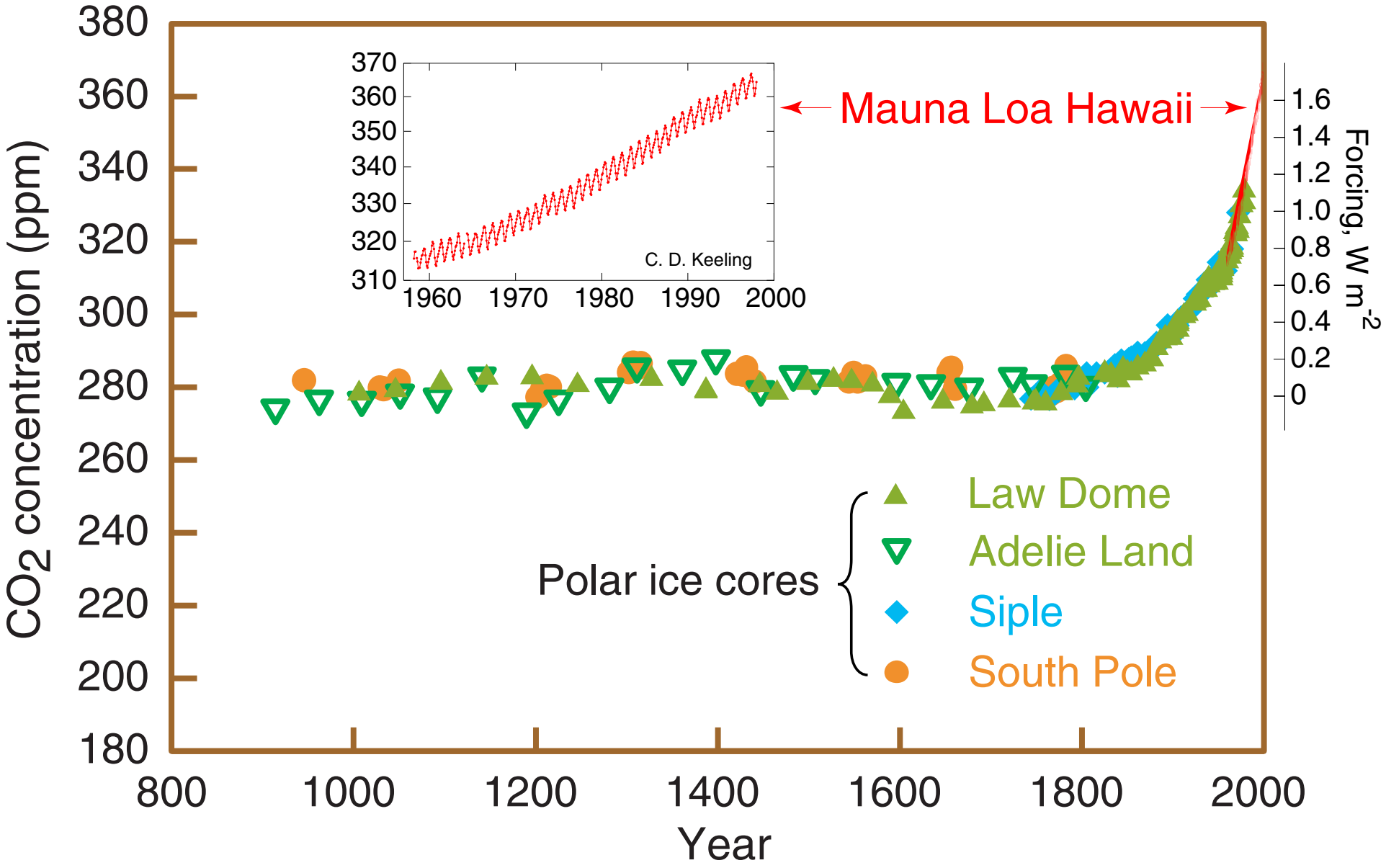
A ***change*** in a component of the Earth's radiation budget.

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



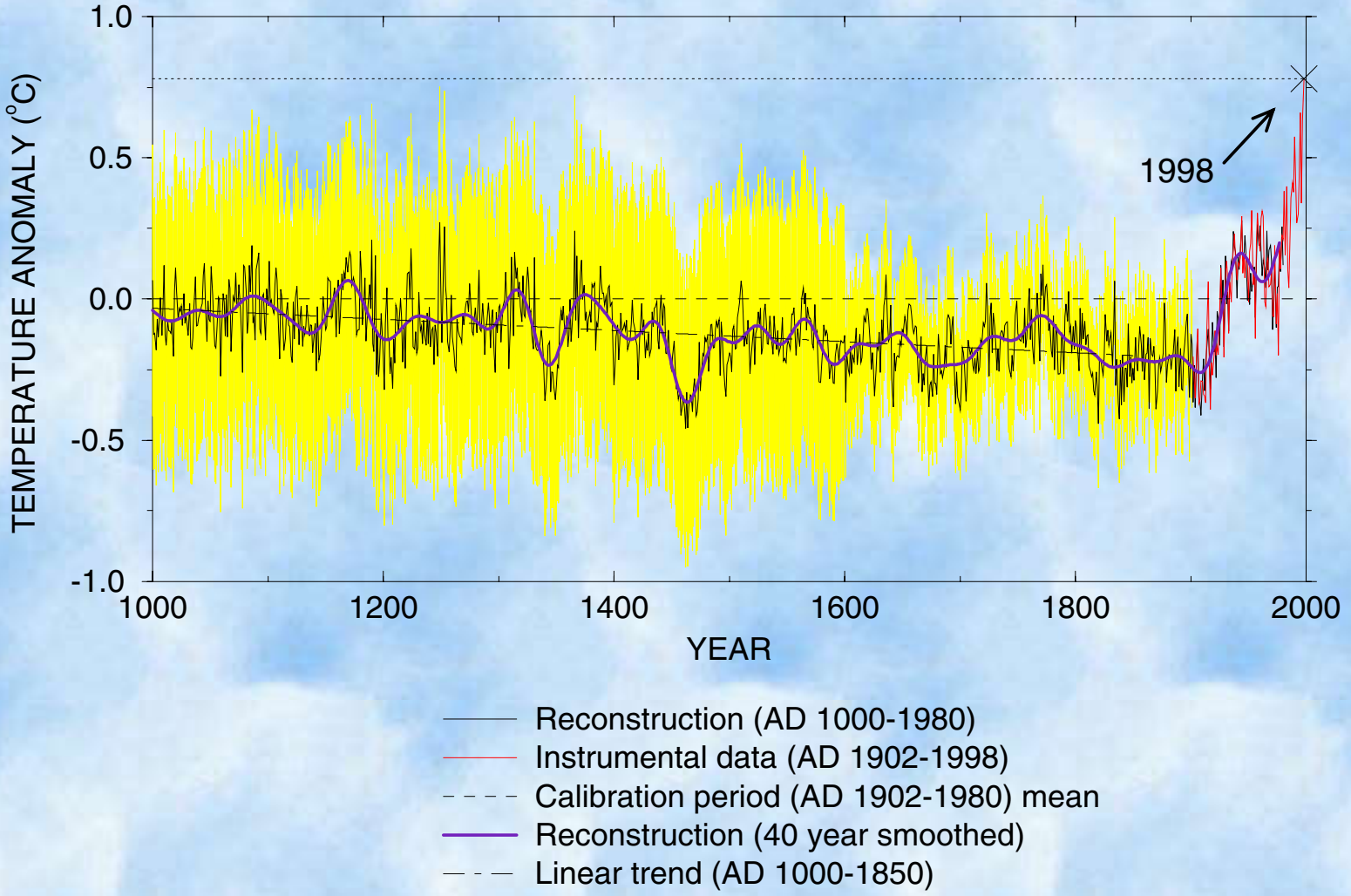
Global carbon dioxide concentration over the last thousand years

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration and infrared radiative forcing over the last thousand years

THE TEMPERATURE'S RISING



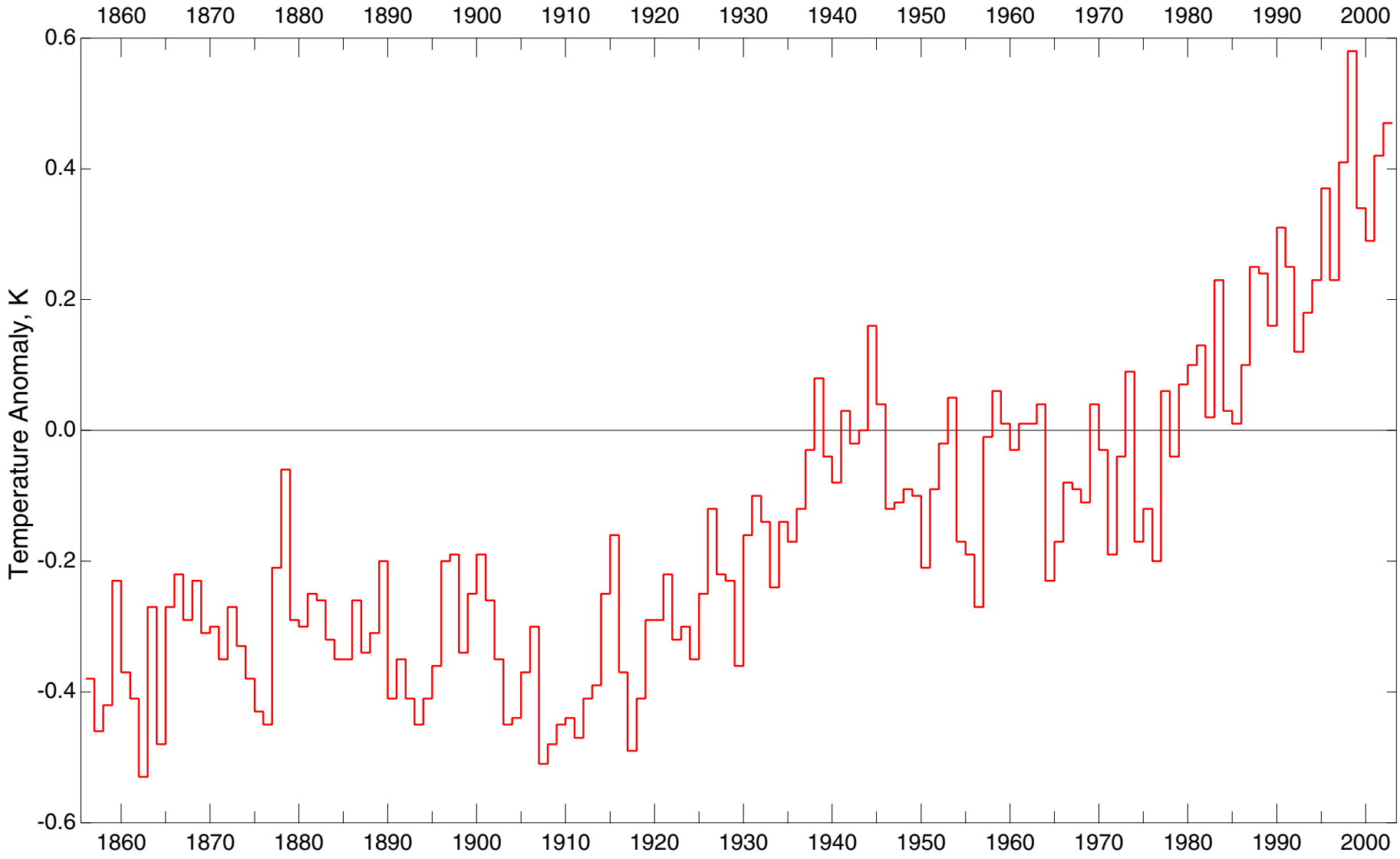
Northern Hemisphere temperature trend (1000-1998), from tree-ring, coral, and ice-core proxy records As calibrated by instrumental measurements.

Mann et al., Geophysical Research Letters, 1999

GLOBAL AVERAGE TEMPERATURE TREND

1856-2002

Temperature Anomaly Relative to Base Period 1961-1990



Climate Research Unit, East Anglia UK

INDICATIONS OF SYSTEMATIC WARMING IN RECENT YEARS

The 1990s were the ***warmest decade*** in the instrumental record.

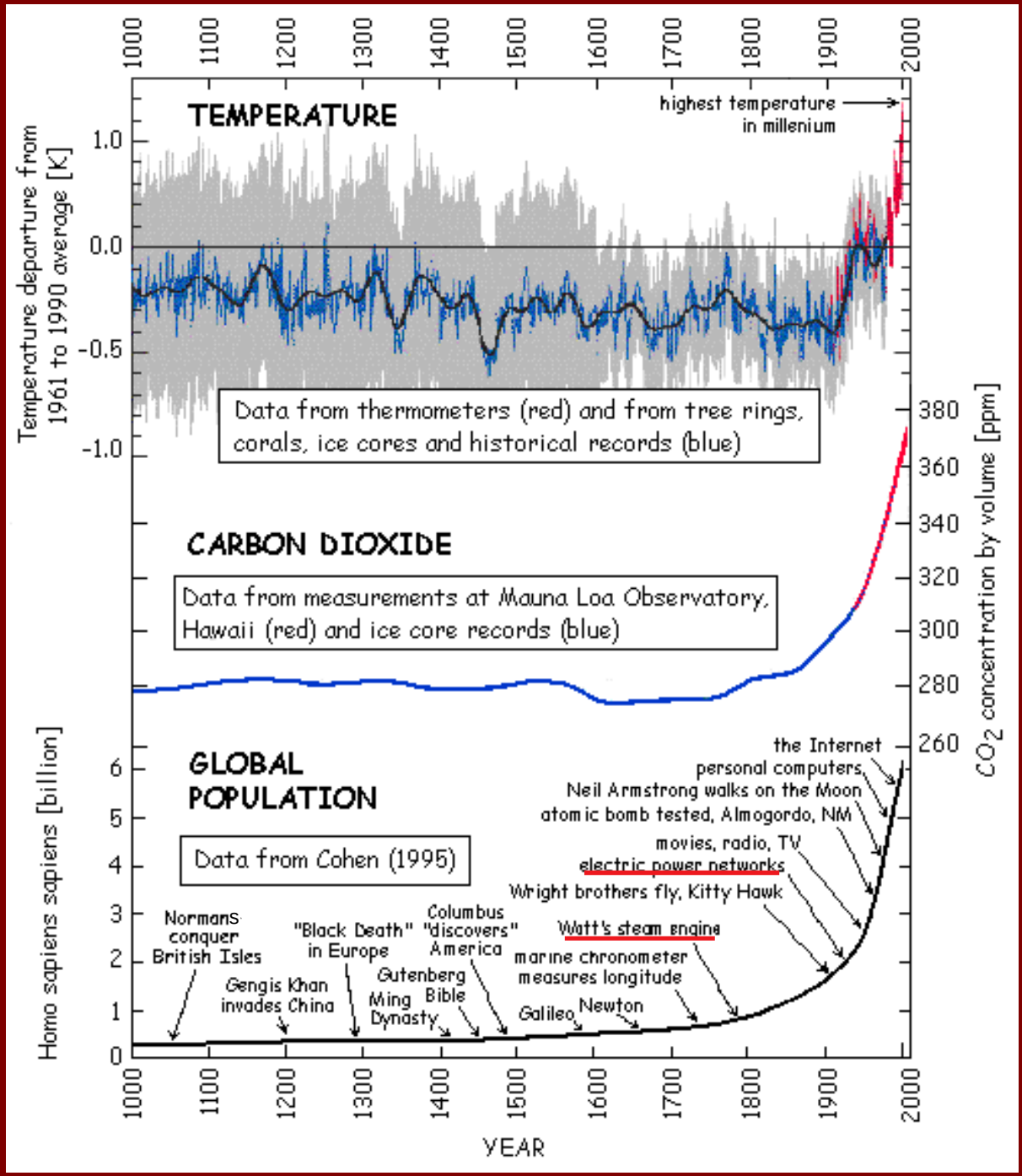
The ***warmest two years*** of the entire instrumental record have been 1998 and 2002.

The ***nine warmest years*** globally have now occurred in the 1990s and 2000s.

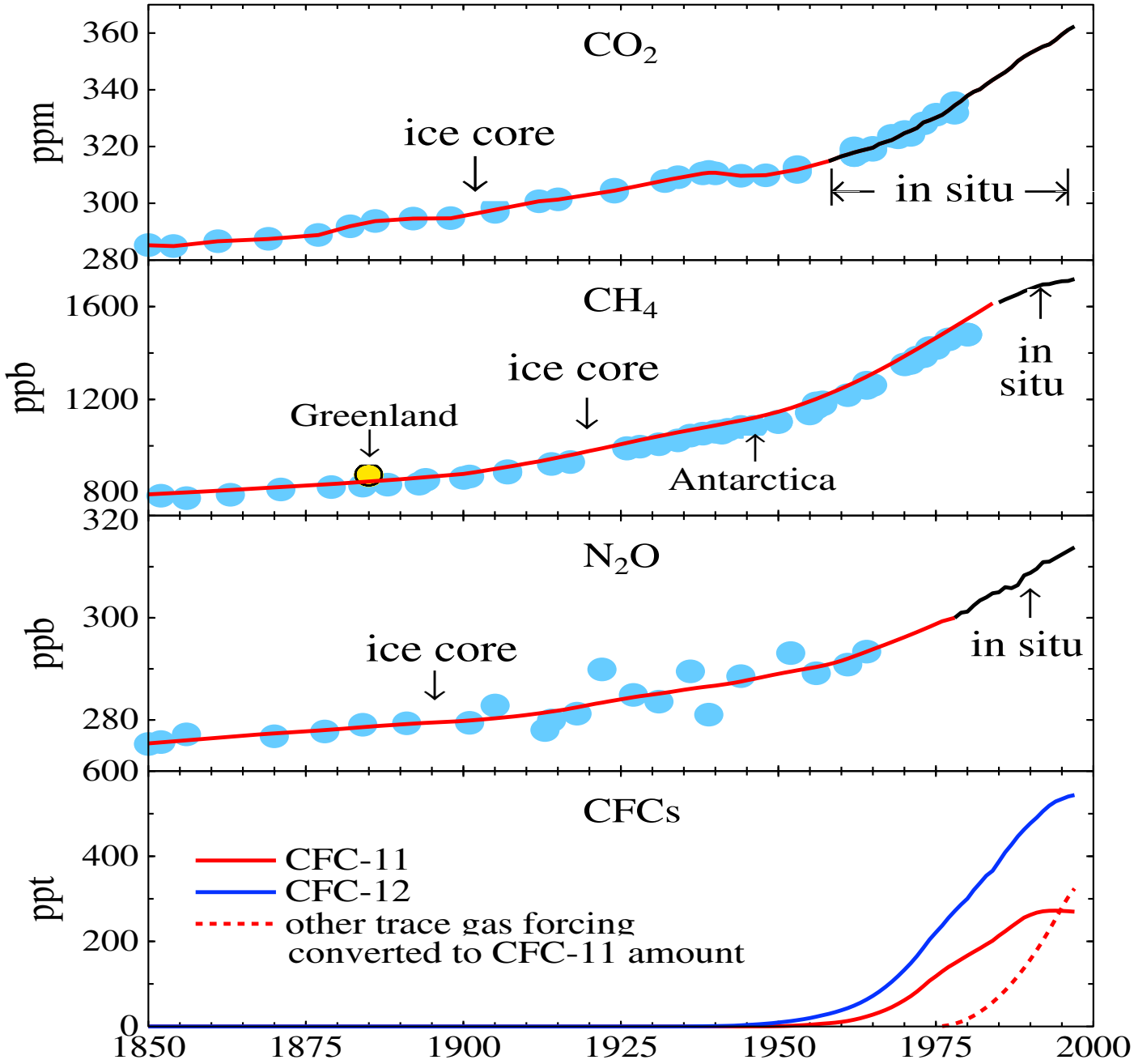
Global warming over the past millennium

Very rapidly we have entered uncharted territory -– what some call the *anthropocene* climate regime. Over the 20th century, human population quadrupled and energy consumption increased sixteenfold. Near the end of the last century, we crossed a critical threshold, and global warming from the fossil fuel greenhouse became a major, and increasingly dominant, factor in climate change. Global mean surface temperature is higher today than it's been for at least a millennium.

Martin Hoffert, NYU

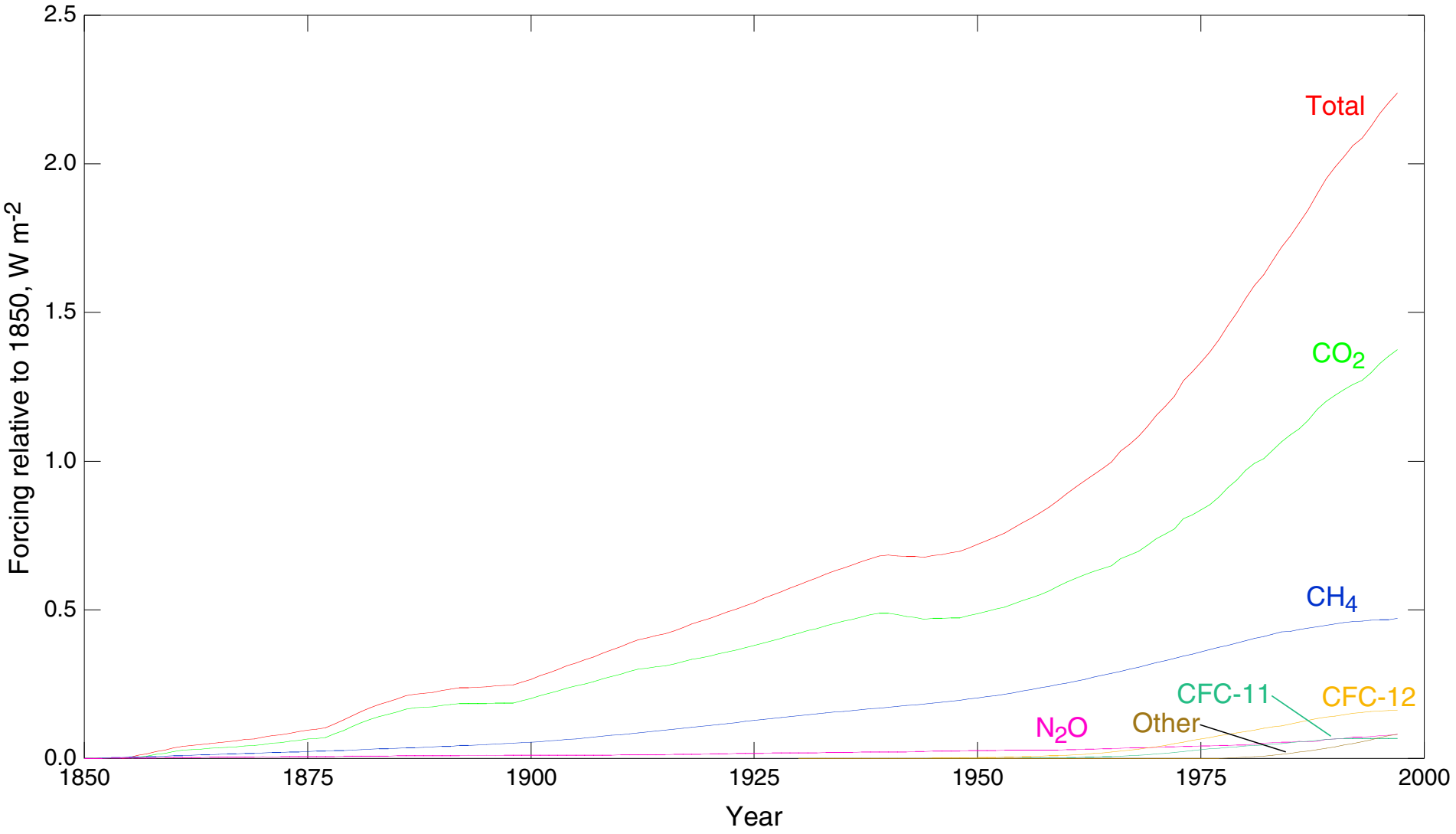


GREENHOUSE GAS MIXING RATIOS OVER THE INDUSTRIAL PERIOD



Hansen *et al.*, PNAS. 1998

GREENHOUSE GAS FORCINGS OVER THE INDUSTRIAL PERIOD



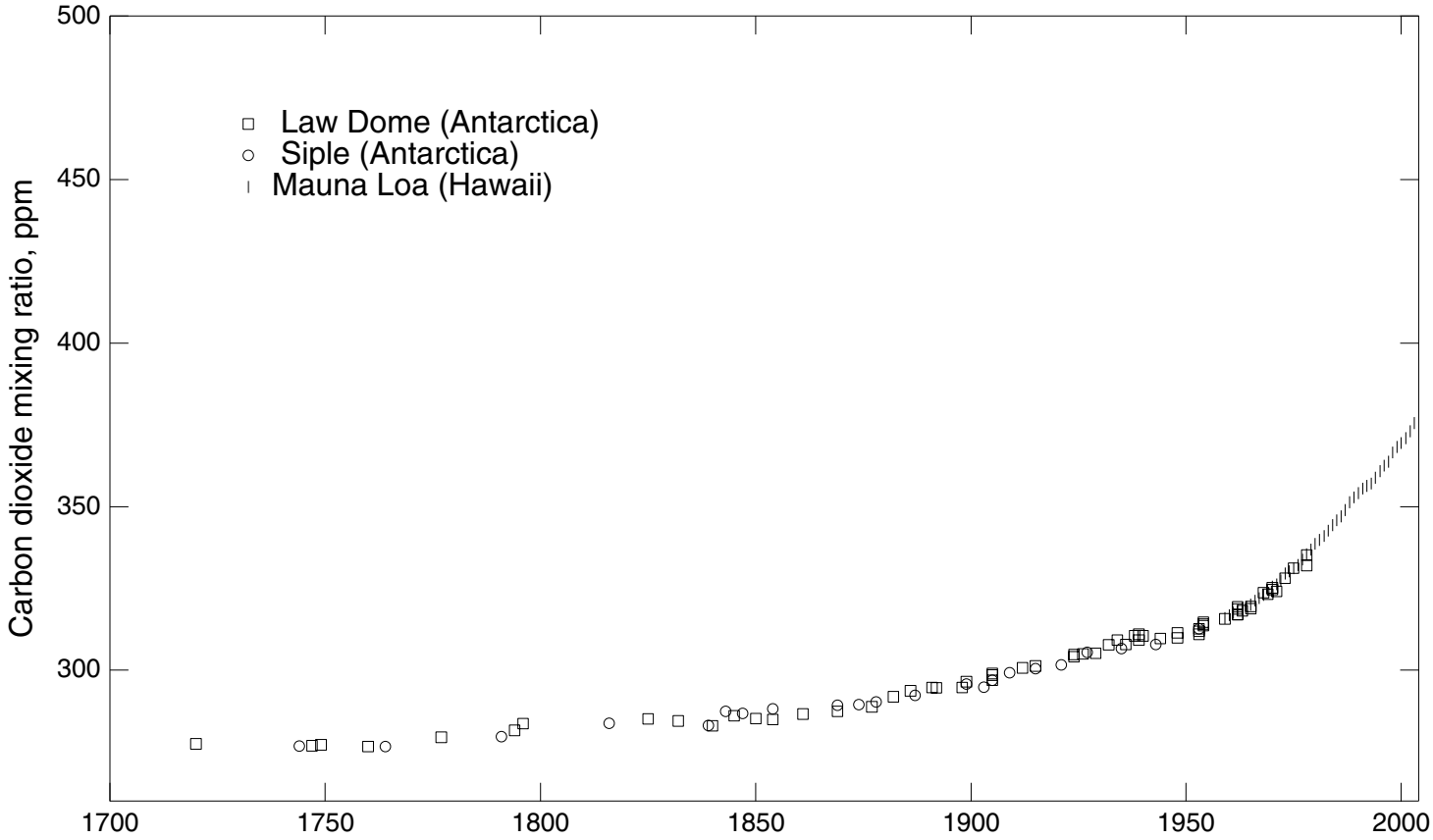
Data: GISS

WHERE IS ALL THIS CO_2 COMING FROM?

WHO IS RESPONSIBLE?

ATMOSPHERIC CARBON DIOXIDE

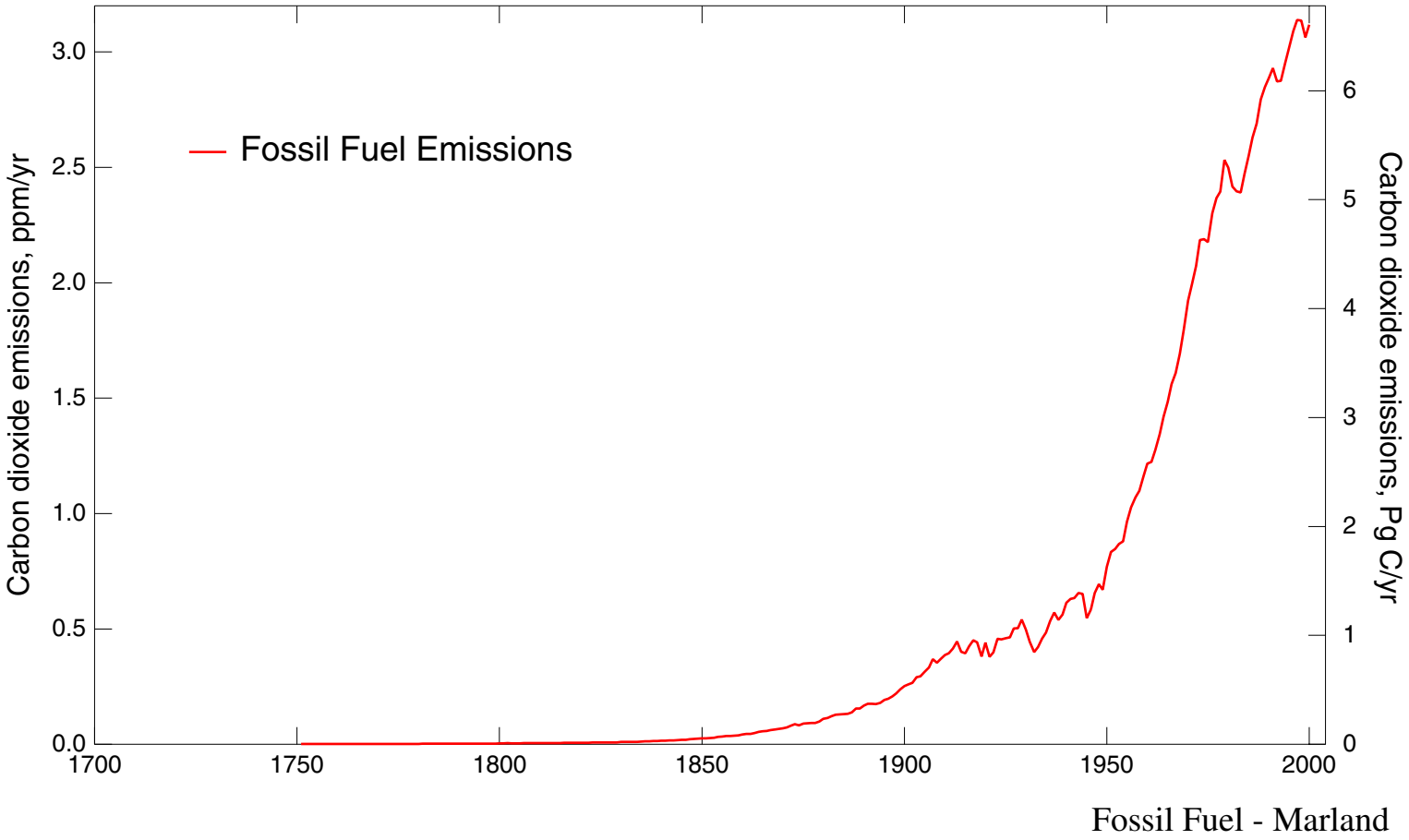
Time series 1700 - 2003



Law - Etheridge et al.
Siple - Friedli et al.
Mauna Loa - Keeling

ATMOSPHERIC CO_2 EMISSIONS

Time series 1700 - 2003



Fossil Fuel - Marland

ATMOSPHERIC CARBON DIOXIDE

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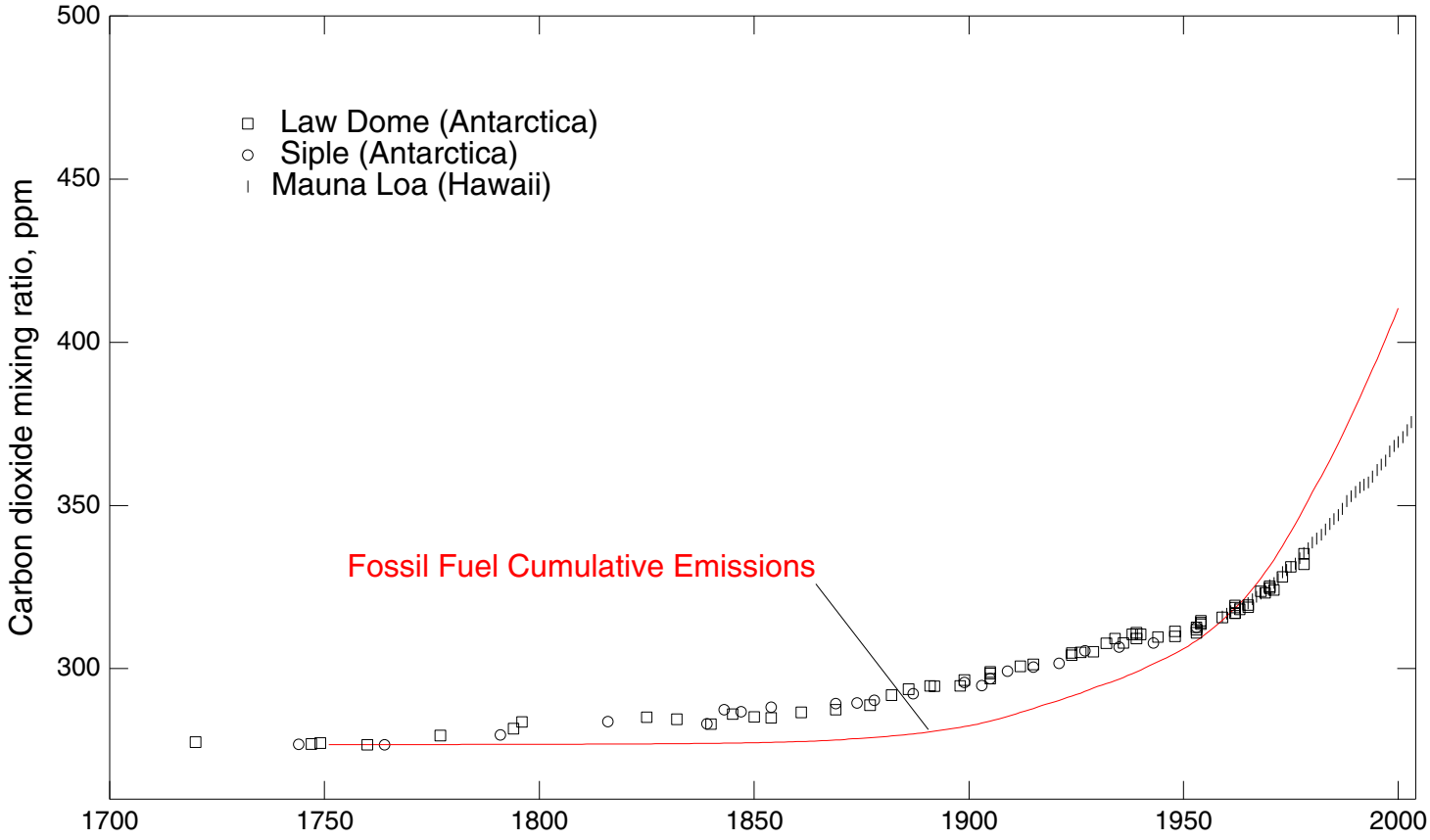

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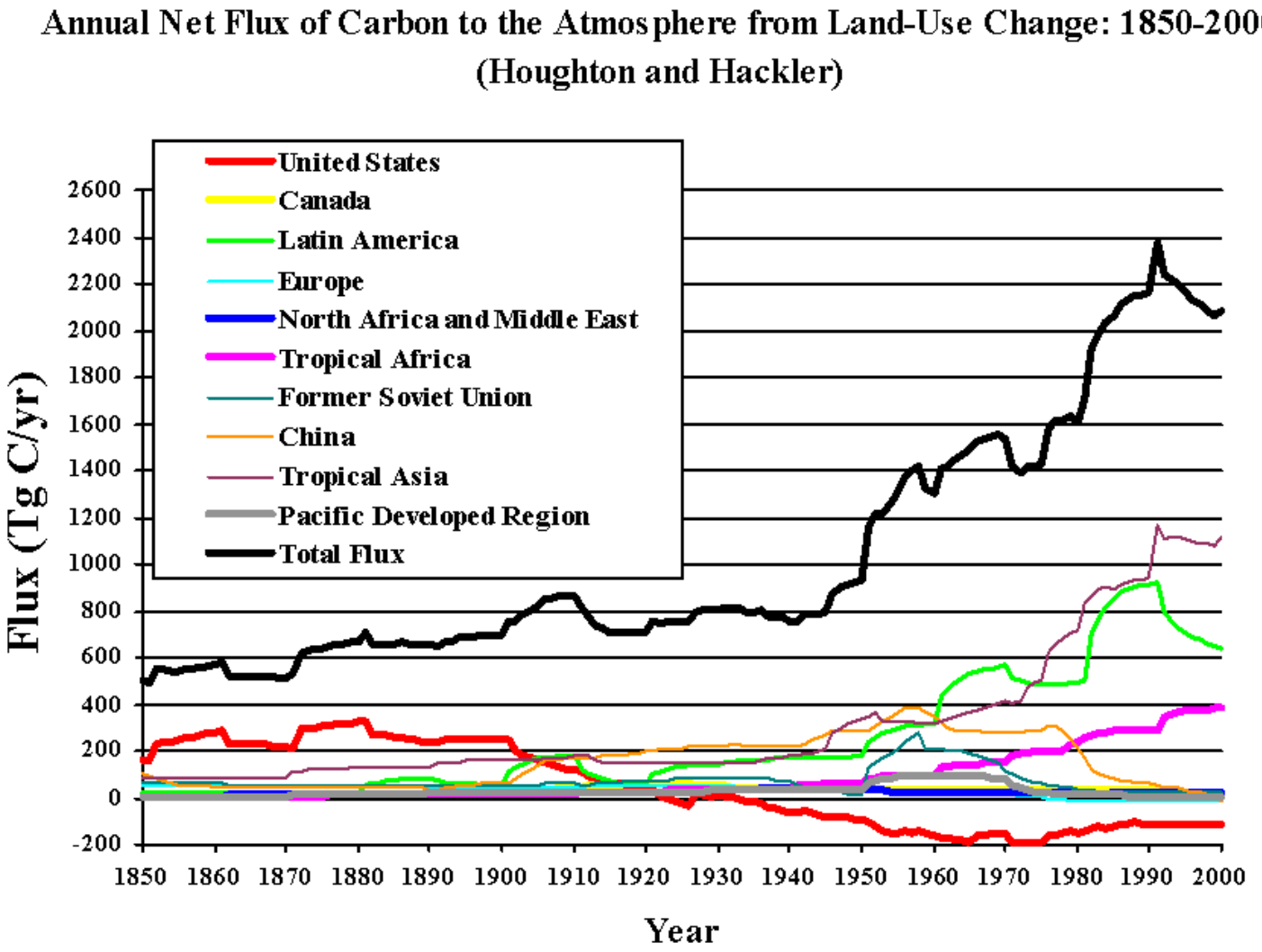
LAND USE CARBON EMISSIONS BY SOURCE REGION



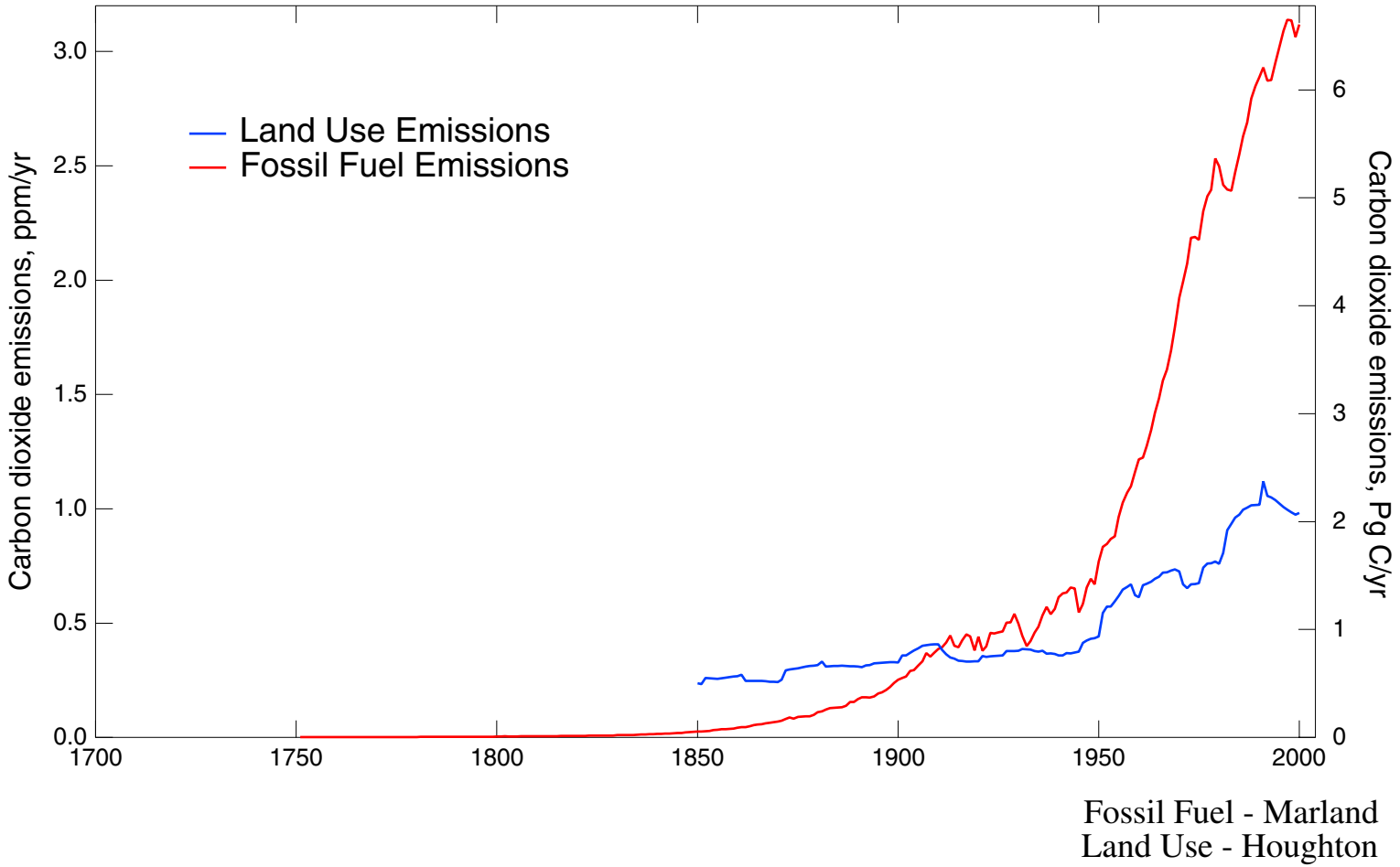
1000 Tg = 1 Pg
= 10^{15} g,
Equivalent to
0.47 ppm

Carbon flux estimated as land area times carbon emissions associated with land clearing or afforestation (uptake).

United States dominates emissions before 1900 and uptake after 1940.

ATMOSPHERIC CO_2 EMISSIONS

Time series 1700 - 2003

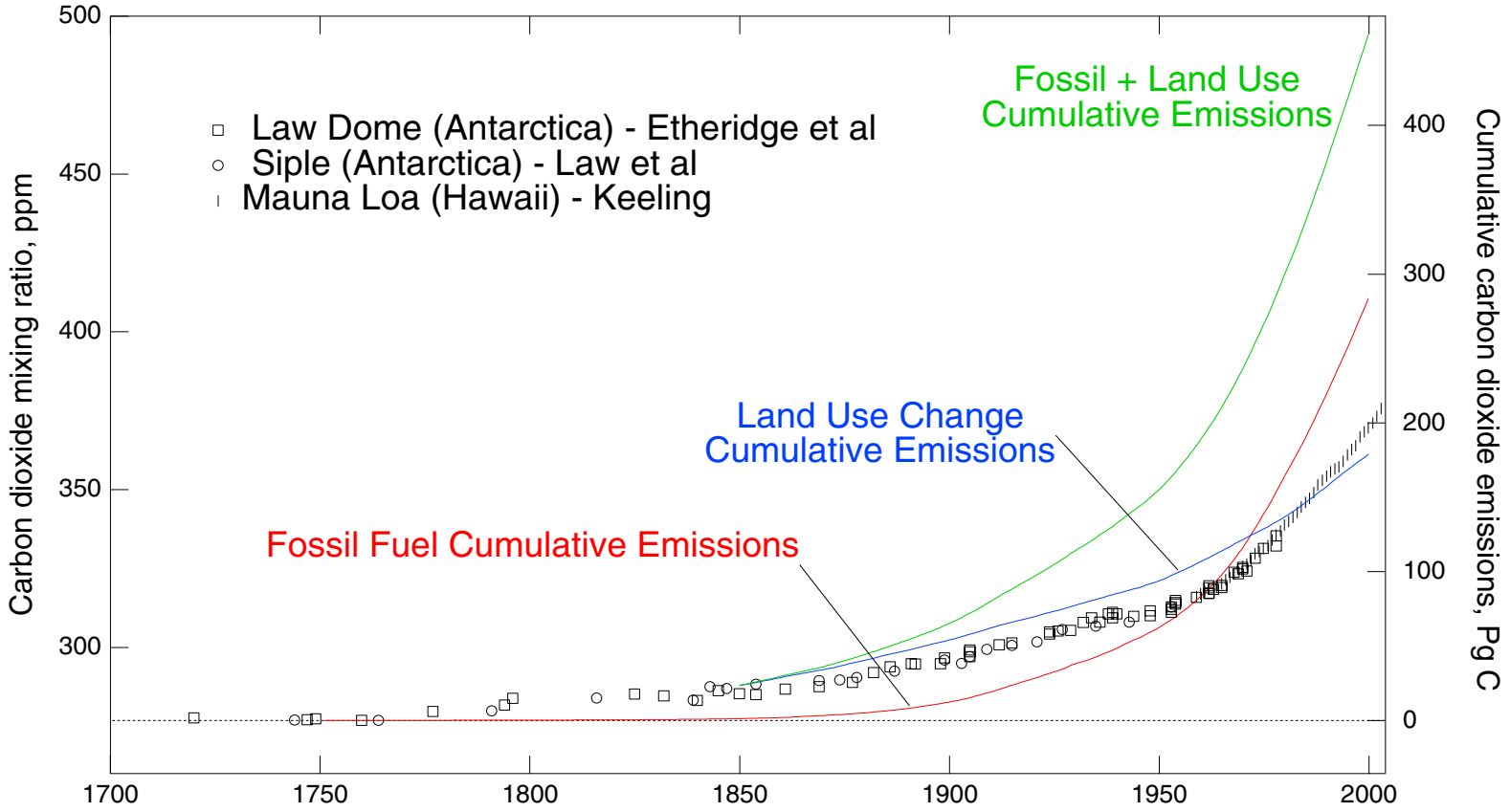


Prior to 1910 CO_2 emissions from land use changes were dominant.

Subsequently fossil fuel CO_2 has been dominant and rapidly increasing!

ATTRIBUTION OF INCREASE IN ATMOSPHERIC CO_2

Comparison of ***cumulative*** CO_2 emissions from fossil fuel combustion and land use changes with measured increases in atmospheric CO_2.



Prior to 1970 the increase in atmospheric CO_2 was dominated by emissions from land use changes, not fossil fuel combustion.

HOW MUCH CARBON IS IN A GALLON OF GASOLINE?

1 lb?

2 lbs?

3 lbs!?

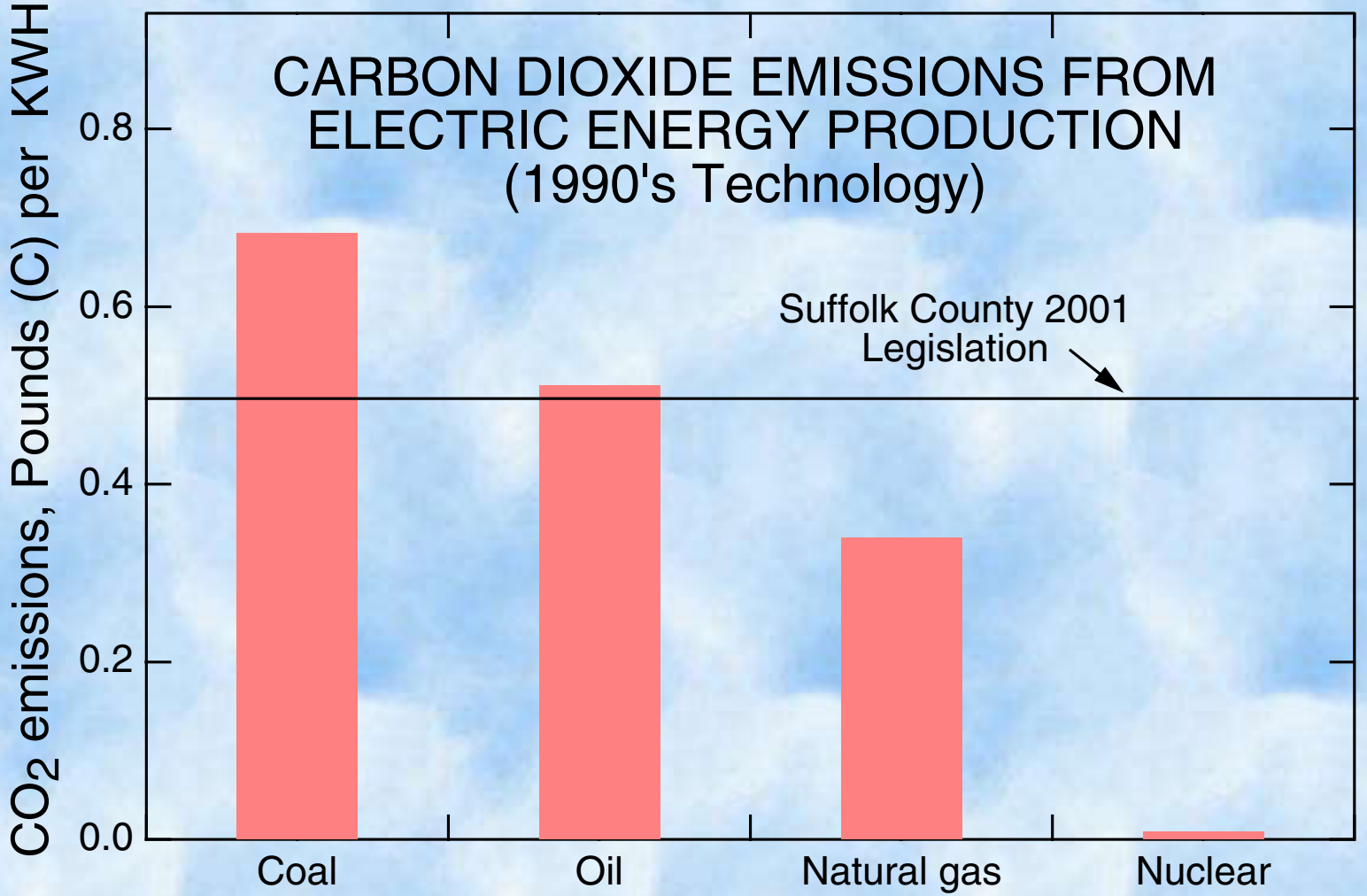
5 lbs!?!

All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

THE MOST EFFECTIVE WAY TO DOUBLE THE FUEL ECONOMY OF A CAR . . .

IS TO PUT TWO PEOPLE IN IT!

YOUR FAMILY'S CONTRIBUTION TO THE GREENHOUSE EFFECT



A typical household using 1000 kilowatt hours of electricity per month is responsible for emission of 3 tons of carbon a year in the form of carbon dioxide.

How much does your household contribute?

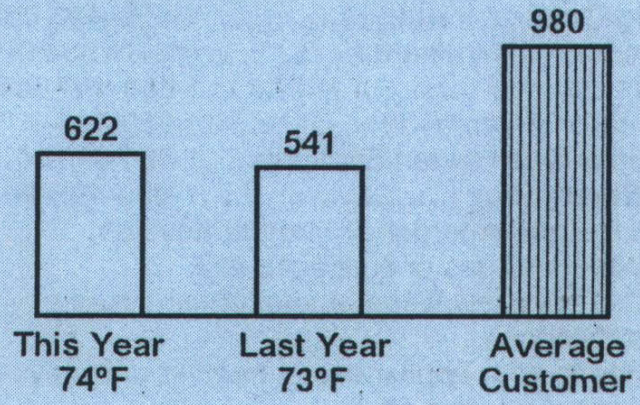
YOUR CONTRIBUTION TO THE GREENHOUSE EFFECT

ELECTRIC SUPPLY AND DELIVERY FROM LIPA

Meter Readings Meter # 15790134

	Jul 24	93155 Actual
	Jun 26	92533 Actual
Use	28 **Days**	622 **KWH**

Comparisons KWH



Cost Rate 880 - Water and Home Heating

Basic Service: 28 Days @ 17.90¢	$5.01
Use: 233 KWH @ 12.49¢	29.10
140 KWH @ 13.67¢	19.14
249 KWH @ 9.78¢	24.35
Excess Fuel Price Surcharge	4.28
PILOTs and Credits	1.40
Shoreham Credit	-.59
Sales Tax: @ 1%	.83
Total	$83.52

LIPA
Long Island Power Authority

Jul 25, 2001	927 20 1805 3 5	1-800-490-0025	See Back Of Bill
Date	Account Number	Any Questions?	Service Problems

At half a pound of carbon per KWH, the average household is responsible for emission of 500 pounds of carbon a month.

Suffolk County Limits CO_2 Emissions

Breath of Fresh Air

Gaffney signs bill to limit greenhouse gas emissions

Newsday July 25, 2001

By Emi Endo

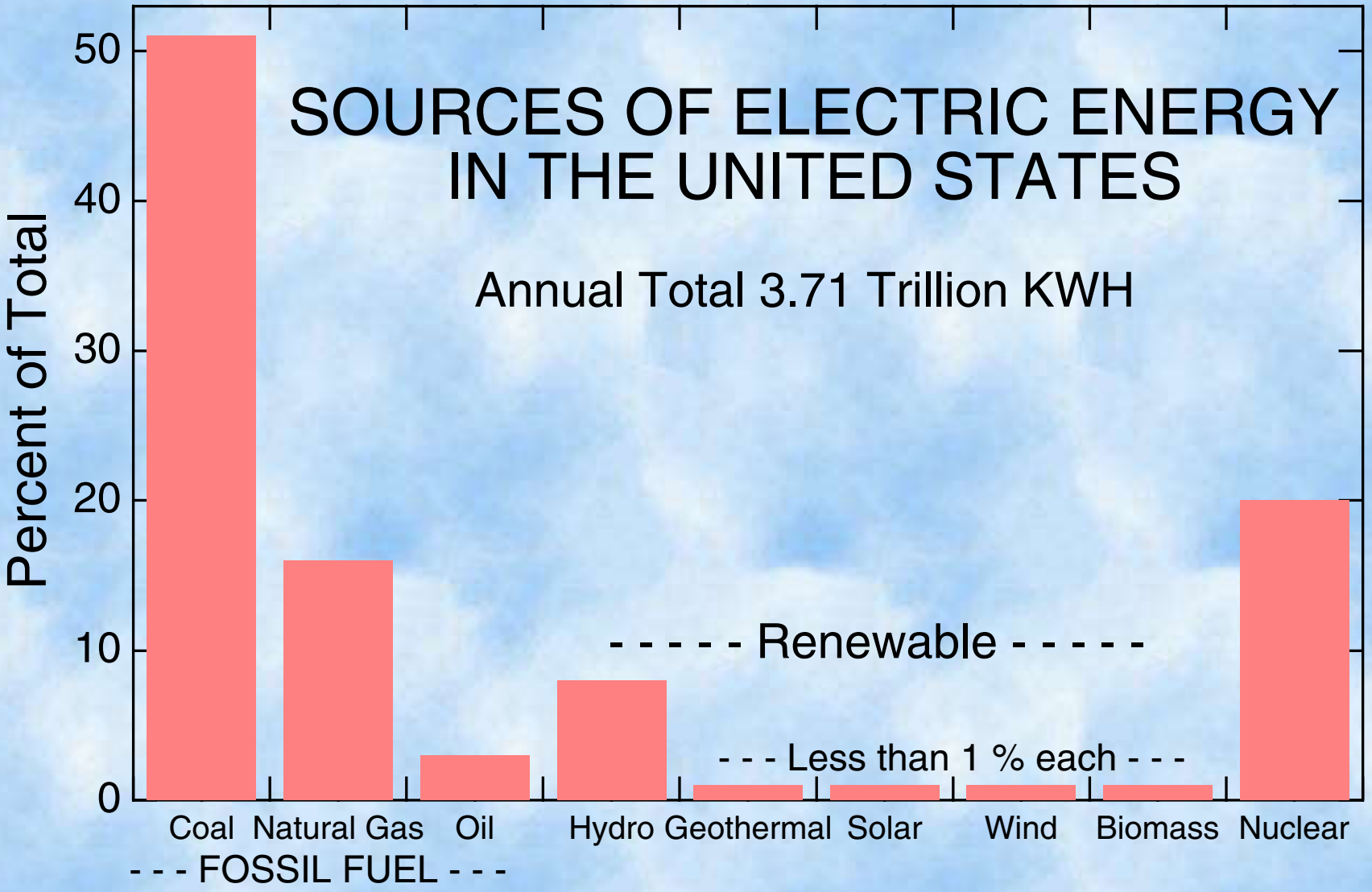
Suffolk County Executive Robert Gaffney yesterday signed into law a bill aimed at limiting greenhouse gas emissions locally, although critics questioned how much it would actually reduce the emissions.

Beginning in March, for every 100 megawatts of new generation added in the county, the emissions rate must be reduced by 1 percent, until a 20-percent reduction is achieved. Power plants that exceed the standard would face fines.

During negotiations, Fisher raised the emissions limit from less than 1,500 pounds to 1,800 pounds of carbon dioxide per megawatt hour and cut the penalties from $5 for each ton of carbon dioxide emissions exceeding the limit to $2.

0.49 lbs Carbon per KWH

WHERE DOES YOUR ELECTRIC ENERGY COME FROM?



On Long Island most electric energy derives from combustion of oil.

WHAT COUNTRY USES THE MOST ELECTRIC POWER?

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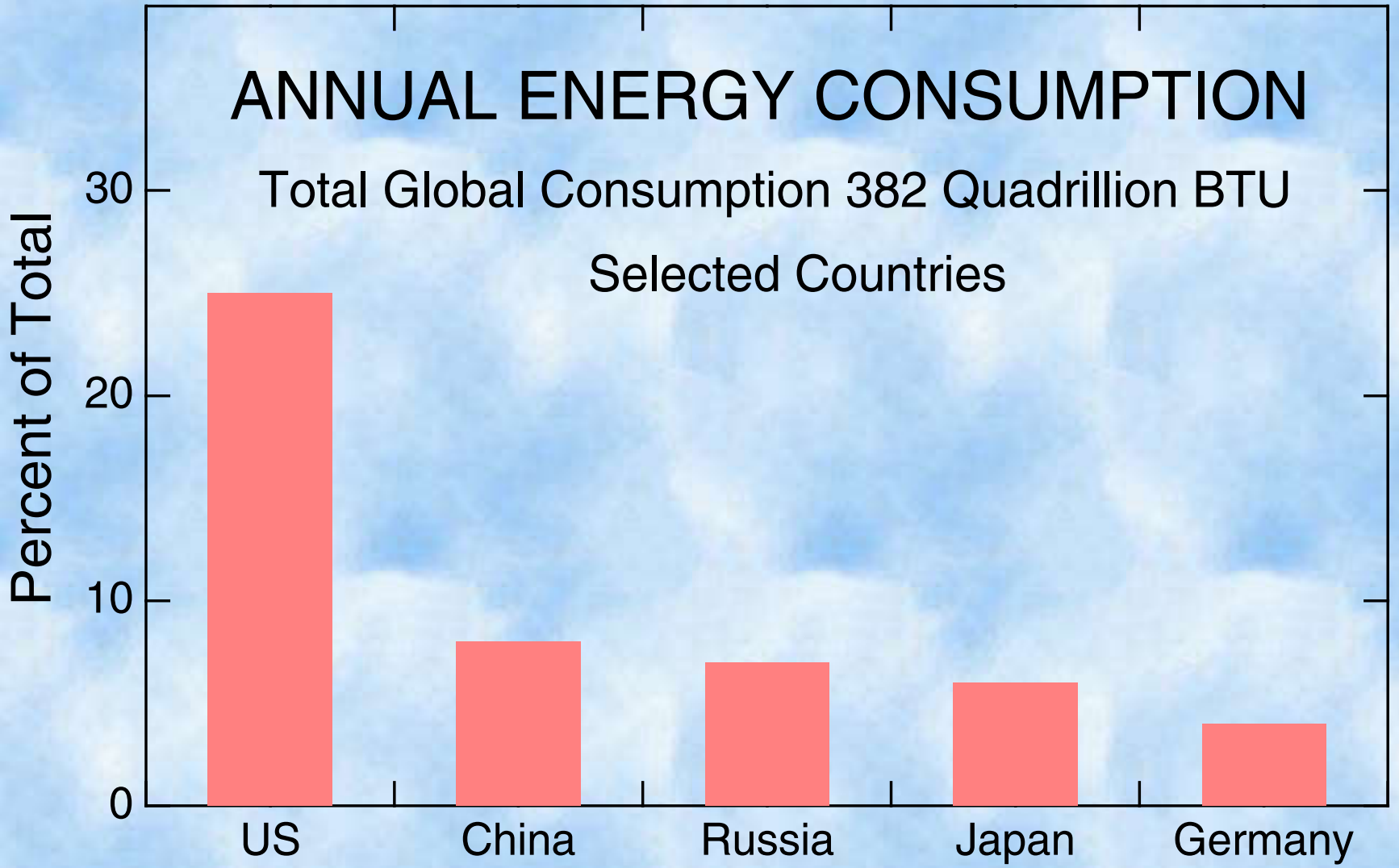
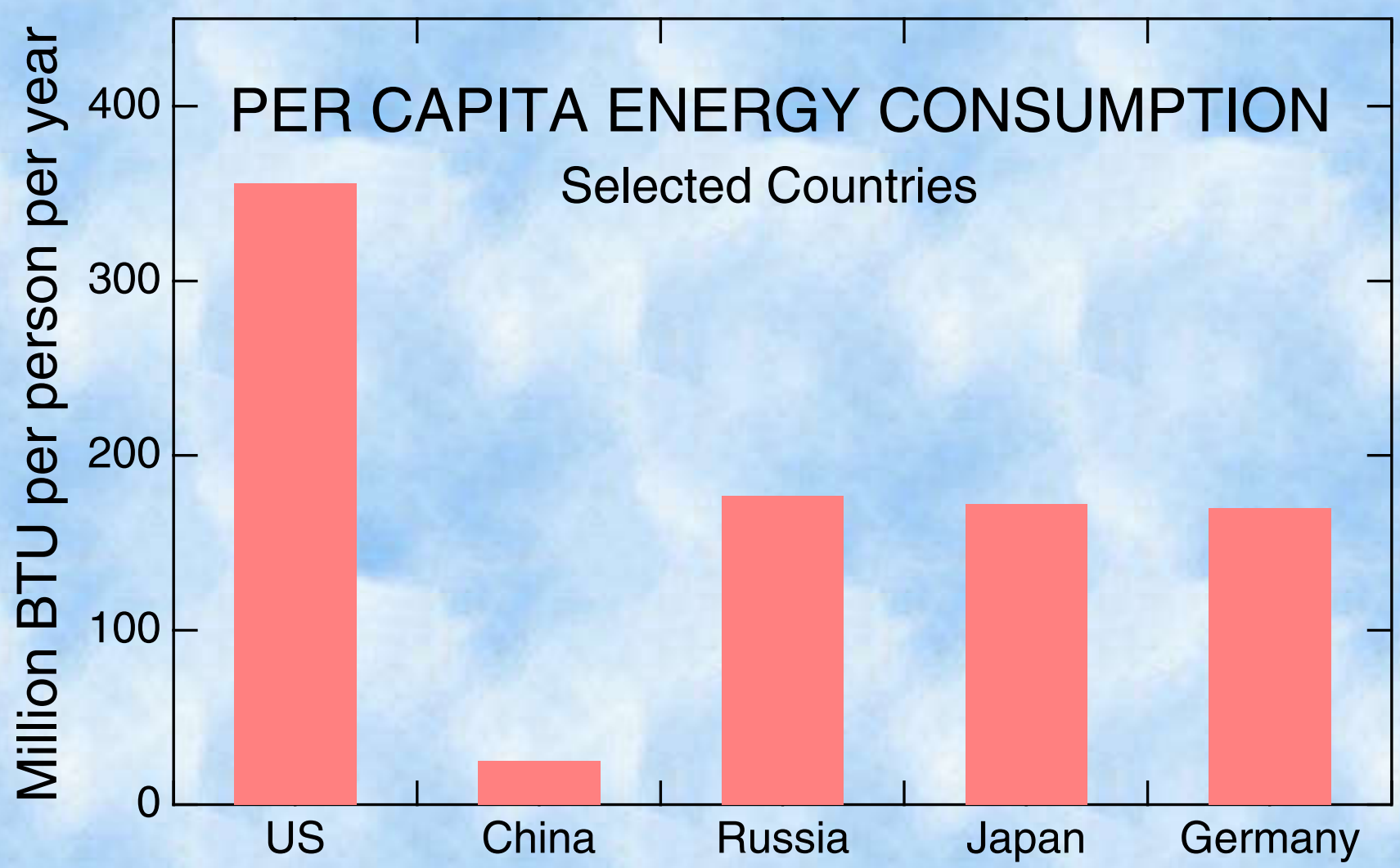


No surprise. It's the United States.

WHAT COUNTRY USES THE MOST ELECTRIC POWER ***PER CAPITA***?

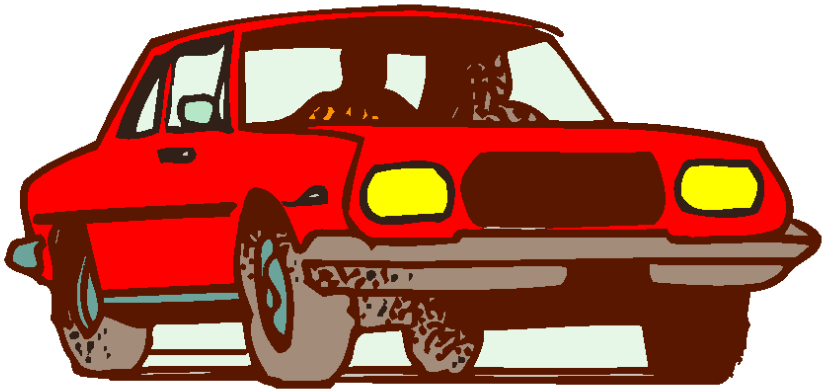
WHAT COUNTRY USES THE MOST ELECTRIC POWER ***PER CAPITA***?



No surprise. It's the United States again.

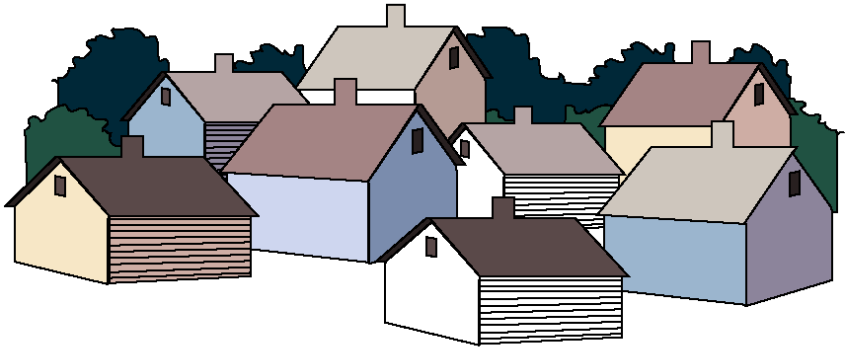
WHERE IS THIS CARBON DIOXIDE COMING FROM?

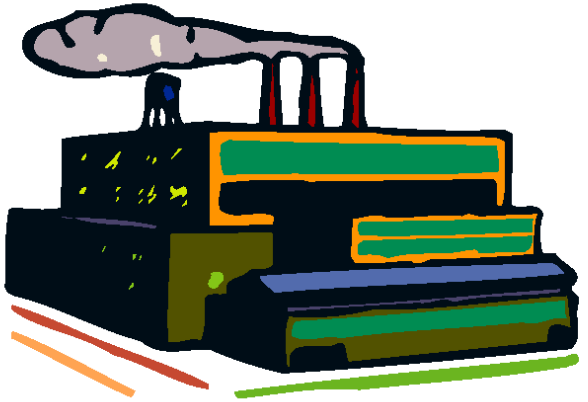
WE ARE ALL RESPONSIBLE.



Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO_2), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.





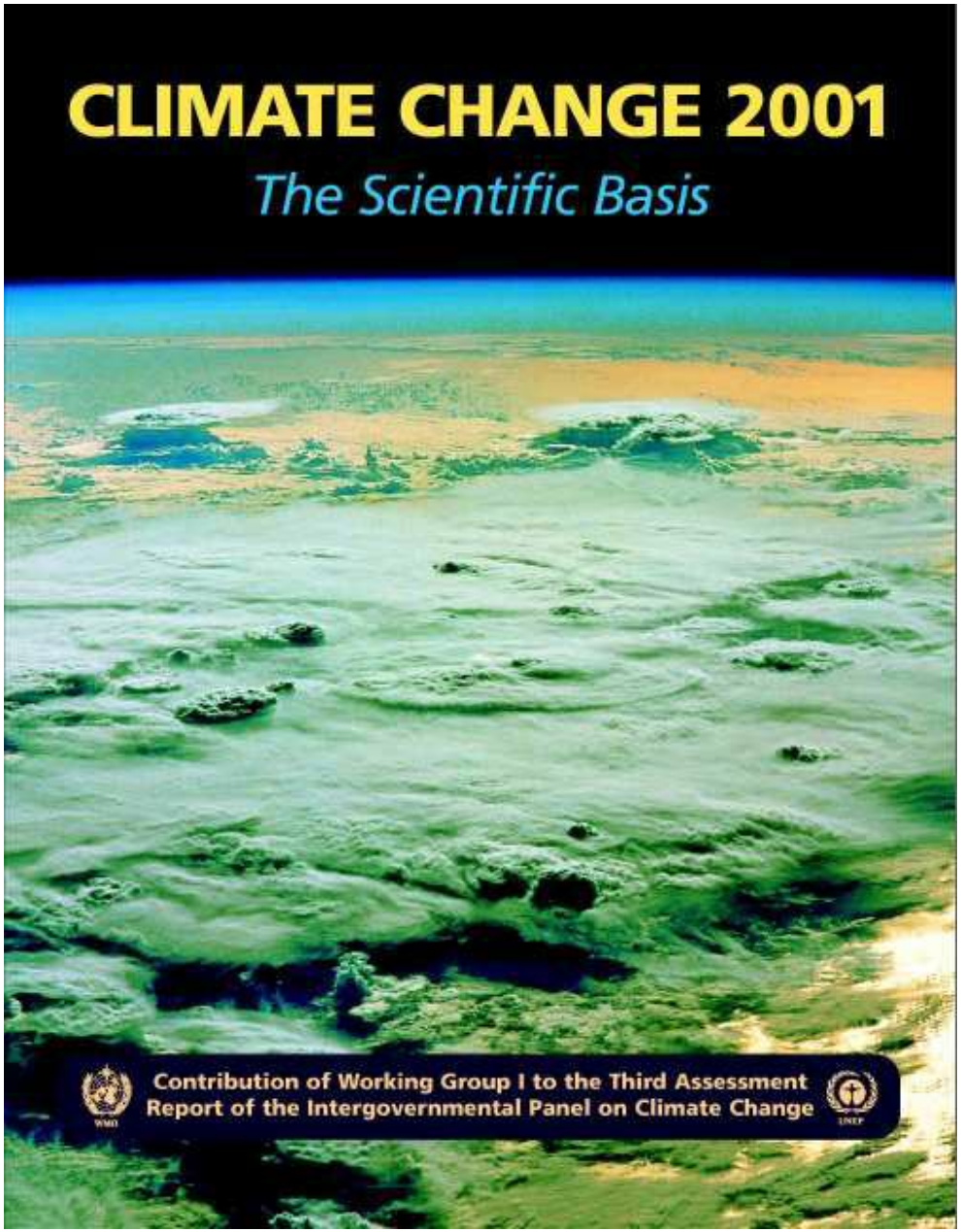
Looking to the Future . . .

Prediction is difficult,
especially about the future.

– Niels Bohr

THE "BIBLE" OF CLIMATE CHANGE RESEARCH

WMO

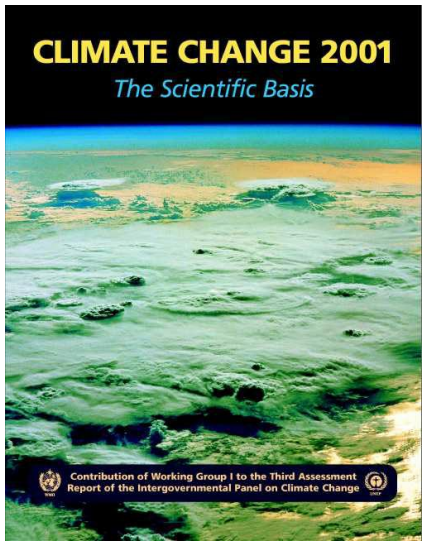


UNEP

Cambridge University Press, 2001

http://www.grida.no/climate/ipcc_tar/wg1/

THE BIBLE OF CLIMATE CHANGE



It's big and thick.

Every household should have one.

No one reads it from cover to cover.

You can open it up on any page and find something interesting.

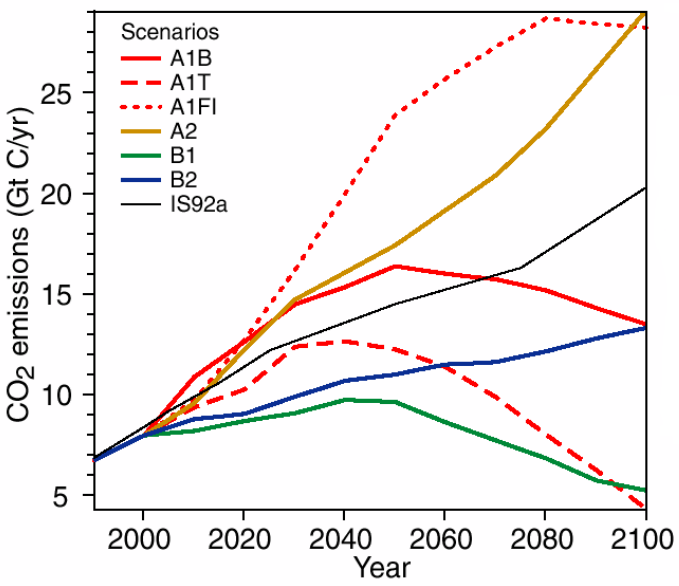
It was written by a committee.

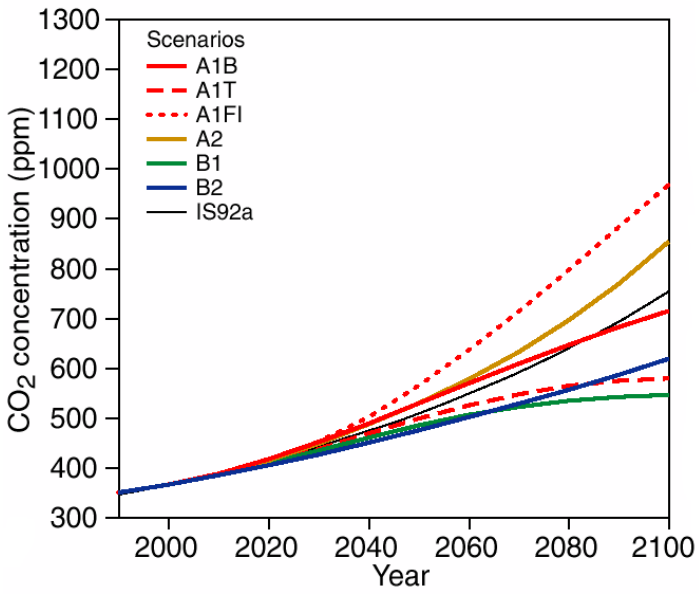
It is full of internal contradictions.

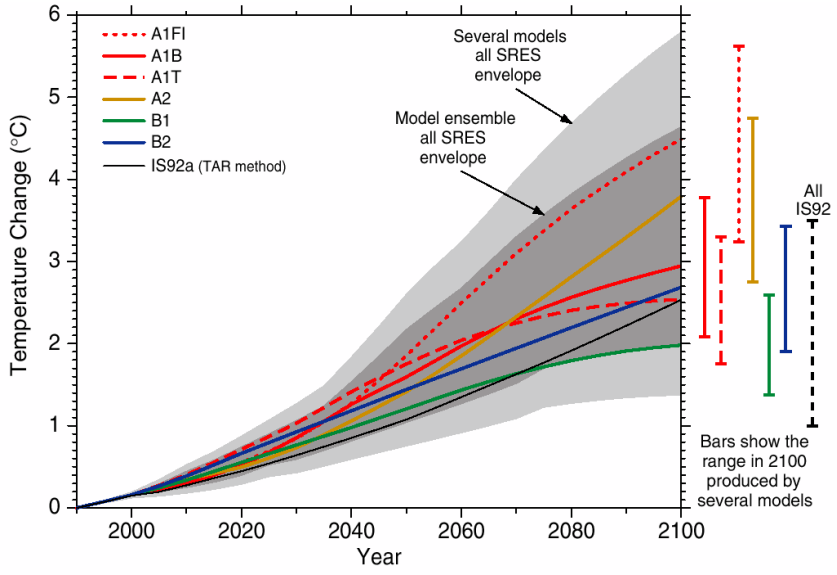
It deals with cataclysmic events such as floods and droughts.

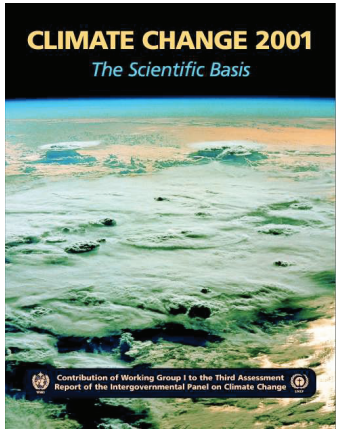
It has its true believers and its rabid skeptics.

FUTURE CLIMATE IS HIGHLY UNCERTAIN









(*IPCC, 2001*)

Contributors to uncertainty include ***emissions***, ***concentrations***, and Earth's ***climate sensitivity***.

Global Atmosphere, Global Warming

QUESTIONS ABOUT GLOBAL WARMING

- IS IT REAL?
- IS IT IMPORTANT?
- WHAT IS IT DUE TO?
- HOW MUCH MORE CAN WE EXPECT?
- ARE WE SEEING JUST THE TIP OF THE ICEBERG?

RESEARCH AT BROOKHAVEN NATIONAL LABORATORY IS HELPING TO ANSWER THESE QUESTIONS.